



**IEEE**

**IEC/IEEE 62704-2**

Edition 1.0 2017-06

# **INTERNATIONAL STANDARD**

## **NORME INTERNATIONALE**



**Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz – Part 2: Specific requirements for finite difference time domain (FDTD) modelling of exposure from vehicle mounted antennas**

**Détermination du débit d'absorption spécifique (DAS) maximal moyenné dans le corps humain, produit par les dispositifs de communications sans fil, 30 MHz à 6 GHz –**

**Partie 2: Exigences spécifiques relatives à la modélisation de l'exposition des antennes sur véhicule, à l'aide de la méthode des différences finies dans le domaine temporel (FDTD)**



## **THIS PUBLICATION IS COPYRIGHT PROTECTED**

**Copyright © 2017 IEC, Geneva, Switzerland**

**Copyright © 2017 IEEE**

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing being secured. Requests for permission to reproduce should be addressed to either IEC at the address below or IEC's member National Committee in the country of the requester or from IEEE.

IEC Central Office  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland  
Tel.: +41 22 919 02 11  
Fax: +41 22 919 03 00  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)

Institute of Electrical and Electronics Engineers, Inc.  
3 Park Avenue  
New York, NY 10016-5997  
United States of America  
[stds.ipr@ieee.org](mailto:stds.ipr@ieee.org)  
[www.ieee.org](http://www.ieee.org)

### **About the IEC**

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### **About the IEEE**

IEEE is the world's largest professional association dedicated to advancing technological innovation and excellence for the benefit of humanity. IEEE and its members inspire a global community through its highly cited publications, conferences, technology standards, and professional and educational activities.

### **About IEC/IEEE publications**

The technical content of IEC/IEEE publications is kept under constant review by the IEC and IEEE. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

#### **IEC Catalogue - [webstore.iec.ch/catalogue](http://webstore.iec.ch/catalogue)**

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

#### **IEC publications search - [www.iec.ch/searchpub](http://www.iec.ch/searchpub)**

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

#### **IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)**

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

#### **Electropedia - [www.electropedia.org](http://www.electropedia.org)**

The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

#### **IEC Glossary - [std.iec.ch/glossary](http://std.iec.ch/glossary)**

65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

#### **IEC Customer Service Centre - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)**

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: [csc@iec.ch](mailto:csc@iec.ch).



IEEE

IEC/IEEE 62704-2

Edition 1.0 2017-06

# INTERNATIONAL STANDARD

## NORME INTERNATIONALE



**Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz – Part 2: Specific requirements for finite difference time domain (FDTD) modelling of exposure from vehicle mounted antennas**

**Détermination du débit d'absorption spécifique (DAS) maximal moyenné dans le corps humain, produit par les dispositifs de communications sans fil, 30 MHz à 6 GHz –**

**Partie 2: Exigences spécifiques relatives à la modélisation de l'exposition des antennes sur véhicule, à l'aide de la méthode des différences finies dans le domaine temporel (FDTD)**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

ICS 17.220.20

IEC ISBN 978-2-8322-4259-9  
IEEE ISBN 978-1-5044-4116-2

**Warning! Make sure that you obtained this publication from an authorized distributor.  
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

## CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references .....	8
3 Terms and definitions .....	8
4 Abbreviated terms .....	9
5 Exposure configuration modelling .....	10
5.1 General considerations .....	10
5.2 Vehicle modelling.....	10
5.3 Communications device modelling .....	11
5.4 Exposed subject modelling.....	14
5.5 Exposure conditions.....	15
5.6 Accounting for variations in population relative to the standard human body model.....	18
5.6.1 Whole-body average SAR adjustment factors .....	18
5.6.2 Peak spatial-average SAR adjustment factors .....	20
6 Validation of the numerical models .....	22
6.1 Validation of antenna model.....	22
6.1.1 General .....	22
6.1.2 Experimental antenna model validation.....	22
6.1.3 Numerical antenna model validation .....	23
6.2 Validation of the human body model .....	24
6.3 Validation of the vehicle numerical model .....	26
6.3.1 General .....	26
6.3.2 Vehicle model validation for bystander exposure simulations .....	27
6.3.3 Vehicle model validation for passenger exposure simulations .....	28
7 Computational uncertainty .....	30
7.1 General considerations .....	30
7.2 Contributors to overall numerical uncertainty in standard test configurations.....	31
7.2.1 General .....	31
7.2.2 Uncertainty of the numerical algorithm.....	31
7.2.3 Uncertainty of the numerical representation of the vehicle and pavement.....	31
7.2.4 Uncertainty of the antenna model .....	32
7.2.5 Uncertainty of SAR evaluation in the standard bystander and passenger models.....	33
7.3 Uncertainty budget.....	33
8 Benchmark simulation models .....	34
8.1 General.....	34
8.2 Benchmark for bystander exposure simulations .....	35
8.3 Benchmark for passenger exposure simulations.....	36
9 Documenting SAR simulation results .....	38
9.1 General.....	38
9.2 Test device .....	38
9.3 Simulated configurations.....	38
9.4 Software and standard model validation.....	38

9.5	Antenna numerical model validation.....	38
9.6	Results of the benchmark simulation models.....	38
9.7	Simulation uncertainty.....	39
9.8	SAR results.....	39
Annex A (normative)	File format and description of the standard human body models .....	40
A.1	File format .....	40
A.2	Tissue parameters .....	42
Annex B (informative)	Population coverage.....	47
Annex C (informative)	Peak spatial-average SAR locations for the validation and the benchmark simulation models.....	51
Bibliography.....		52
Figure 1 – Antenna feed model .....		12
Figure 2 – Voltage and current at the matched antenna feed-point.....		13
Figure 3 – Bystander model (left) and passenger/driver model (right) for the SAR simulations .....		15
Figure 4 – Passenger and driver positions in the vehicle for the SAR simulations .....		17
Figure 5 – Bystander positions relative to the vehicle for the SAR simulations .....		17
Figure 6 – Experimental setup for antenna model validation .....		23
Figure 7 – Benchmark configuration for bystander model exposed to a front or back plane wave .....		25
Figure 8 – Benchmark configuration for passenger model exposed to a front or back plane wave .....		26
Figure 9 – Configuration for vehicle numerical model validation .....		27
Figure 10 – Side view (top) and rear view (bottom) benchmark validation configuration for bystander and trunk mount antenna.....		35
Figure 11 – Benchmark validation configuration for passenger and trunk mount antenna .....		37
Table 1 – Pavement model parameters .....		14
Table 2 – Whole-body average SAR adjustment factors for the bystander and trunk mount antennas .....		19
Table 3 – Whole-body average SAR adjustment factors for the bystander and roof mount antennas .....		19
Table 4 – Whole-body average SAR adjustment factors for the passenger and trunk mount antennas .....		19
Table 5 – Whole-body average SAR adjustment factors for the passenger and roof mount antennas .....		20
Table 6 – Peak spatial-average SAR adjustment factors for the bystander model and trunk mount antennas .....		21
Table 7 – Peak spatial-average SAR adjustment factors for the bystander model and roof mount antennas .....		21
Table 8 – Peak spatial-average SAR adjustment factors for the passenger model and trunk mount antennas .....		21
Table 9 – Peak spatial-average SAR adjustment factors for the passenger model and roof mount antennas .....		22
Table 10 – Peak spatial-average SAR for 1 g and 10 g and whole-body average SAR for the front and back plane wave exposure of the 3-mm resolution bystander model.....		25

Table 11 – Peak spatial-average SAR for 1 g and 10 g and whole-body average SAR for the front and back plane wave exposure of the 3-mm resolution passenger model.....	26
Table 12 – Antenna length for the vehicle model validation configurations .....	27
Table 13 – The reference electric field (top) and magnetic field (bottom) values for the numerical validation of the vehicle model for bystander exposure .....	28
Table 14 – Coordinates of the test points for the standard vehicle validation simulations for the passenger .....	29
Table 15 – The reference electric field (top) and magnetic field (bottom) values for the numerical validation of the vehicle model for passenger exposure .....	30
Table 16 – Numerical uncertainty budget for exposure simulations with vehicle mounted antennas and bystander and/or passenger models .....	34
Table 17 – Reference SAR values for the bystander benchmark validation model.....	36
Table 18 – Reference SAR values for the passenger benchmark validation model .....	37
Table A.1 – Voxel counts in each data file .....	41
Table A.2 – Tissues and the associated RGB colours in the binary data file.....	41
Table A.3 – Cole–Cole parameters and density for the standard human body model tissues .....	43
Table A.4 – Relative dielectric constant and conductivity for the standard human body model at selected reference frequencies .....	45
Table B.1 – Whole-body average SAR adjustment factors for the bystander model and trunk mount antenna .....	47
Table B.2 – Whole-body average SAR adjustment factors for the bystander model and roof mount antenna.....	48
Table B.3 – Whole-body average SAR adjustment factors for the passenger model and trunk mount antenna .....	48
Table B.4 – Whole-body average SAR adjustment factors for the passenger model and roof mount antenna.....	48
Table B.5 – Peak spatial-average SAR adjustment factors for the bystander model and trunk mount antenna .....	49
Table B.6 – Peak spatial-average SAR adjustment factors for the bystander model and roof mount antenna.....	49
Table B.7 – Peak spatial-average SAR adjustment factors for the passenger model and trunk mount antenna .....	49
Table B.8 – Peak spatial-average SAR adjustment factors for the passenger model and roof mount antenna .....	50
Table C.1 – Location of the peak spatial-average SAR for the front and back plane wave exposure of the standard human body models .....	51
Table C.2 – Location of the peak spatial-average SAR for the vehicle mounted antenna benchmark simulation models .....	51

# **DETERMINING THE PEAK SPATIAL-AVERAGE SPECIFIC ABSORPTION RATE (SAR) IN THE HUMAN BODY FROM WIRELESS COMMUNICATIONS DEVICES, 30 MHz TO 6 GHz –**

## **Part 2: Specific requirements for finite difference time domain (FDTD) modelling of exposure from vehicle mounted antennas**

### **FOREWORD**

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation.

IEEE Standards documents are developed within IEEE Societies and Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of IEEE and serve without compensation. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards. Use of IEEE Standards documents is wholly voluntary. *IEEE documents are made available for use subject to important notices and legal disclaimers (see <http://standards.ieee.org/IPR/disclaimers.html> for more information).*

IEC collaborates closely with IEEE in accordance with conditions determined by agreement between the two organizations. This Dual Logo International Standard was jointly developed by the IEC and IEEE under the terms of that agreement.

- 2) The formal decisions of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees. The formal decisions of IEEE on technical matters, once consensus within IEEE Societies and Standards Coordinating Committees has been reached, is determined by a balanced ballot of materially interested parties who indicate interest in reviewing the proposed standard. Final approval of the IEEE standards document is given by the IEEE Standards Association (IEEE-SA) Standards Board.
- 3) IEC/IEEE Publications have the form of recommendations for international use and are accepted by IEC National Committees/IEEE Societies in that sense. While all reasonable efforts are made to ensure that the technical content of IEC/IEEE Publications is accurate, IEC or IEEE cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications (including IEC/IEEE Publications) transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC/IEEE Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC and IEEE do not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC and IEEE are not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or IEEE or their directors, employees, servants or agents including individual experts and members of technical committees and IEC National Committees, or volunteers of IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board, for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC/IEEE Publication or any other IEC or IEEE Publications.
- 8) Attention is drawn to the normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that implementation of this IEC/IEEE Publication may require use of material covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. IEC or IEEE shall not be held responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patent Claims or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

International Standard IEC/IEEE 62704-2 has been prepared by IEC technical committee 106: Methods for the assessment of electric, magnetic, and electromagnetic fields associated with

human exposure, in cooperation with International Committee on Electromagnetic Safety of the IEEE Standards Association<sup>1</sup>, under the IEC/IEEE Dual Logo Agreement.

This publication is published as an IEC/IEEE Dual Logo standard.

The text of this standard is based on the following IEC documents:

FDIS	Report on voting
106/391/FDIS	106/392/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

This standard contains attached files in the form of CAD model datasets described in Annex A. These files are also available at:

[http://www.iec.ch/dyn/www/f?p=103:227:0:::FSP\\_ORG\\_ID,FSP\\_LANG\\_ID:1303,25](http://www.iec.ch/dyn/www/f?p=103:227:0:::FSP_ORG_ID,FSP_LANG_ID:1303,25)

A list of all parts in the IEC/IEEE 62704 series, published under the general title *Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz*, can be found on the IEC website.

The IEC technical committee and IEEE technical committee have decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

**IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.**

<sup>1</sup> A list of IEEE participants can be found at the following URL: [http://standards.ieee.org/downloads/62704-2/62704-2-2017/62704-2-2017\\_wg-participants.pdf](http://standards.ieee.org/downloads/62704-2/62704-2-2017/62704-2-2017_wg-participants.pdf).



## INTRODUCTION

Computational techniques have reached a level of maturity which allows their use in compliance assessments of wireless communication devices with vehicle mounted antennas. The increasing complexity of assessing product compliance with exposure standards according to specific absorption rate (SAR) limits calls for new compliance techniques. This technique should be time efficient and cost effective. Experimental compliance assessments for wireless communication devices used in combination with vehicles are extremely complex to perform or even not possible at all. National regulatory bodies (e.g. US Federal Communications Commission) encouraged the development of consensus standards as well as the establishment of the related IEEE TC34 SC2 subcommittee and IEC PT62704-2 working group. The benefits to the user include standardized and accepted protocols, standardized anatomical models, validation techniques, benchmark data, reporting format, means for estimating the overall uncertainty in order to produce valid, accurate, repeatable, and reproducible results.

The results obtained by following the protocols specified in this document represent a conservative estimate of the peak spatial-average and whole-body average SAR induced in the standard human body models and exposure conditions established for this document inside or nearby the vehicles representing typical use cases with transmitting mobile radios. The protocols set forth in this document produce results subject to modelling, simulations and other uncertainties that are defined in this document.

The standardized vehicle and human models, test configurations, and related results are representative of the typical exposure conditions expected by the passengers and bystanders near the vehicle with vehicle mounted antennas. It is not the intent of this document to provide a result representative of the absolute maximum SAR value possible under every conceivable combination of body size, posture, vehicle model, and distance from the vehicle and antenna. The following items are described in detail: simulation concepts, simulation techniques, finite difference time domain (FDTD) numerical method, benchmarking techniques, standardized anatomically correct human body models of the passenger and bystander, exposure conditions, reference exposure configurations for validation of the SAR simulation software, and the limitations of these models and tools when used for simulating the peak spatial-average and whole-body average SAR. Procedures for validating the numerical tools used for SAR simulations and assessing the SAR simulation uncertainties are provided. This document is intended primarily for use by engineers and other specialists who are familiar with electromagnetic (EM) theory, numerical methods, and, in particular, FDTD techniques. This document does not recommend specific SAR limit values since these are found in other documents.

# DETERMINING THE PEAK SPATIAL-AVERAGE SPECIFIC ABSORPTION RATE (SAR) IN THE HUMAN BODY FROM WIRELESS COMMUNICATIONS DEVICES, 30 MHz TO 6 GHz –

## Part 2: Specific requirements for finite difference time domain (FDTD) modelling of exposure from vehicle mounted antennas

### 1 Scope

This part of IEC/IEEE 62704 establishes the concepts, techniques, validation procedures, uncertainties and limitations of the finite difference time domain technique (FDTD) when used for determining the peak spatial-average and whole-body average specific absorption rate (SAR) in a standardized human anatomical model exposed to the electromagnetic field emitted by vehicle mounted antennas in the frequency range from 30 MHz to 1 GHz, which covers typical high power mobile radio products and applications. This document specifies and provides the test vehicle, human body models and the general benchmark data for those models. It defines antenna locations, operating configurations, exposure conditions, and positions that are typical of persons exposed to the fields generated by vehicle mounted antennas. The extended frequency range up to 6 GHz will be considered in future revisions of this document. This document does not recommend specific peak spatial-average and whole-body average SAR limits since these are found in other documents, e.g. IEEE C95.1-2005, ICNIRP (1998).

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050 (all parts), *International Electrotechnical Vocabulary (IEV)* (available at: <http://www.electropedia.org>)

IEC/IEEE 62704-1:—2, *Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz – Part 1: General requirements for using the finite difference time domain (FDTD) method for SAR calculations*

IEEE Standards Dictionary Online (subscription available at: <http://ieeexplore.ieee.org/xpls/dictionary.jsp>)

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC/IEEE 62704-1:—, the IEEE Standards Dictionary Online, IEC 60050 (all parts) and the following apply.

#### 3.1

##### **bystander model**

heterogeneous human body model in the standing posture defined in this document to represent a bystander near the standardized vehicle

---

<sup>2</sup> Under preparation. Stage at time of publication: IEC/IEEE FDIS 62704-1:2016.